Effects of Gamma Irradiation on Prickly Pear Cactus

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On May 11, 1965, a 12-year-old field on the AEC Savannah River Plant was exposed for 400 hours to a 9200 curie ^{137}Cs irradiator (Monk 1965). The field vegetation was typical of abandoned farmland on the dry, excessively drained Lakeland sandy soils with annuals predominant in number of individuals. Scattered through the exposed portion of the community were forty-five plants of prickly pear cactus (*Opuntia compressa* (Salisb.) Macbr.). At the time of exposure most of the cactus plants were in a similar flowering stage. Each plant had fully opened flowers at the beginning of the exposure and many possessed flower buds which did not open until the termination of irradiation. The precise stage of micro- and megasporogenesis was unknown. Prior to and at various periods following exposure a number of biological measurements were made on each plant. This paper represents a report on the effects of irradiation on prickly pear.

Methods

Twelve days prior to radiation exposure, the number of stem segments, new vegetative buds, and flower buds were recorded for each plant in the population. On August 23, the number of stem segments and fruits per plant were counted. In early November all fruits were collected for measurement of diameter and seeds per fruit were counted. The seeds were dried at room temperature for one week and those of each plant were weighed collectively then planted in the field for germination studies. Except for germination tests similar measurements were made in 1966.

The radiation exposure of each plant was monitored by Toshiba Low Z phosphate glass rods. The rods were placed in opaque plastic vials to minimize fading due to sunlight (Blaylock and Witherspoon 1965).

Results and Discussion

The forty-five plants were arranged in descending order of radiation exposure. The means of the biological data and rate of radiation exposure were calculated for each successive group of five plants (Tables 1-2). The basic form and position of the data were not materially affected by the data treatment. The actual range in R/hr was 31.3 to 0.1.

All flower and vegetative buds aborted on plants receiving in excess of 22.5 R/hr. Plants with exposures greater than 27.5 R/hr died within a month following irradiation. Subsequently, all plants included in the 23.5 R/hr exposure level (Table 1) died except for one plant exposed at a rate of 18.7 R/hr.

Fruit size, seed weight, and seeds per fruit were more radiation sensitive than fruit and stem segment survival in 1965 (Table 1). The former three exhibited a marked reduction between 2.9 and 5.9 R/hr. Fruit survival began to decrease at the same radiation level, however, variability was too large for the trend to be signifi-

TABLE 1

Effects of 400 hours of high dose irradiation on a population of prickly pear cactus. Each figure represents a mean for five plants with one standard error.

	R/HR				
	30.4 ±1.5	23.5 ±1.4	13.0 ±0.9	9.3 ±0.5	5.9 ±0.5
1965					
Fruit Survival (%)	0	0	52.8±16.3	56.4±10.5	61.0±11.7
Fruit Diameter (Cm)	—	—	1.0± 0.0	1.3± 0.1	1.2± 0.0
Seeds/Fruit	—	—	5.2± 0.6	11.9± 1.3	8.3± 1.6
Seed Weight (Mg)	—	—	19.4± 5.7	22.4± 2.5	29.4± 2.1
Stem Segment Survival (%)	—	11.2± 9.8	71.6± 8.4	85.8± 7.8	86.9± 5.2
1966					
Fruit Survival (%)	0	0	12.2±11.1	32.5±13.7	56.8± 8.1
Fruit Diameter (Cm)	—	—	1.9± 0.1	1.9± 0.1	1.6± 0.0
Seeds/Fruit	—	—	34.5± 1.9	25.5± 2.9	23.4± 5.3
Seed Weight (Mg)	—	—	22.1± 4.1	21.5± 3.7	21.3± 3.9
1966/1965 Flower Bud Production (%)	—	35.2±20.0	25.3±19.3	27.7± 8.7	48.7±17.0
1966/1965 Vegetative Bud Production (ratio)	—	0.51	1.67	7.00	1.00

cant. All of the non-aborted fruits contained seeds, many of which possessed only one. This fact tended to extend the radiation tolerance as well as increase the variability of that biological parameter. Stem segment survival was not materially affected until the 23.5 R/hr isodose line.

The germination response was similar to the data presented in Table 1, however, germination percentages were too low in the controls for the experiment to be conclusive. Seeds from plants receiving 9.3 R/hr or more were generally less viable than those from plants with less exposure.

TABLE 2

Effects of 400 hours of low dose irradiation on a population of prickly pear cactus. Each figure represents a mean for five plants with on standard error.

	R/HR				
	2.9 ±0.3	1.4 ±0.1	0.9 ±0.1	0.3 ±0.0	0.0
1965					
Fruit Survival (%)	66.6± 5.8	72.2± 3.7	81.2± 5.8	73.0±11.5	79.2± 9.9
Fruit Diameter (Cm)	1.6± 0.1	1.4± 0.1	1.5± 0.1	1.9± 0.1	1.7± 0.1
Seeds/Fruit	25.6± 1.3	27.4± 1.6	27.6± 1.8	23.5± 2.1	19.6± 3.7
Seed Weight (Mg)	38.7± 2.8	29.3± 2.1	31.3± 2.4	32.8± 8.2	32.0± 3.8
Stem Segment Survival (%)	92.4± 4.4	95.7± 3.1	98.4± 1.6	79.0± 8.6	90.6± 4.3
1966					
Fruit Survival (%)	65.7± 5.3	69.5±11.3	79.7±14.9	62.5±13.2	71.8± 6.1
Fruit Diameter (Cm)	1.6± 0.0	1.7± 0.1	1.5± 0.1	1.7± 0.1	1.8± 0.1
Seeds/Fruit	20.5± 1.1	27.2± 2.5	18.7± 4.3	23.0± 3.1	25.7± 1.2
Seed Weight (Mg)	35.0± 4.3	34.1± 4.1	30.5± 3.4	31.3± 3.6	31.1± 4.0
1966/1965 Flower Bud Production(%)	56.2±14.6	63.5±16.8	74.2±11.1	69.7± 8.6	64.5±13.1
1966/1965 Vegetative Bud Production (ratio)	0.71	0.19	0.50	0.75	0.19

One year following irradiation, the prickly pear cactus population still exhibited a response to exposure. All plants with less than 17.5 R/hr produced flower buds in 1966. Flower bud production in 1966 was consistently lower than in 1965. Those plants exposed to 9.3 R/hr or more were less productive than the rest of the population (Table 1).

In 1966, no fruits survived on plants receiving in excess of 13.6 R/hr. Fruit survival in 1966 was slightly less at lower exposures than in 1965 and considerably lower at the higher radiation levels (Table 1). Fruit size and seeds per fruit were not affected in 1966, however, seed weight tended to be lower at the higher exposures.

Certain segments of the cactus population formed more vegetative buds in 1966 than in 1965 while the remainder produced less (Table 1). The ratio of 1966/1965 new stem segments was higher in those plants at the 13.0-5.9 R/hr levels than in those exposed at higher or lower levels.

The enhancement of vegetative bud production at the 13.0-5.9 R/hr levels could be interpreted as a stimulatory effect for which evidence exists both for (Sax 1963) and against (Skok *et al.*, 1965). However, in light of continued reduction of flower bud production, fruit survival, and lighter seeds in 1966, the enhancement of vegetative bud formation may represent a radiation induced imbalance in the normal development in cactus whereby the plant reserves are channelled more into vegetative recovery. Survival from radiation damage in a small segment of a plant population is dependent upon vegetative recovery or the production of viable seeds. If either of these recovery mechanisms is enhanced at the expense of the other, it is difficult to view the enhancement in terms of a "true" stimulatory response but rather as a compensatory recovery mechanism.

Summary

The irradiation effects on prickly pear may be summarized as follows:

(1) Exposures in excess of 18.7 R/hr administered over a 400 hour period are lethal.

(2) Exposures of 5.9 R/hr are sufficient to cause a major reduction in fruit size, seeds per fruit, and seed weight and a slight reduction in fruit survival.

(3) Stem segment survival is reduced at 13.0 R/hr.

(4) One year following irradiation, flower bud production and fruit survival are decreased in plants receiving in excess of 5.9 R/hr while vegetative recovery is greatest in plants exposed at 13.0-5.9 R/hr.

(5) The enhancement of vegetative bud production in 1966 may be a recovery mechanism from radiation induced damage rather than a "true" stimulatory response to radiation.

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